

Implementation of Web-based Training System for Mathematics using Evaluation Functions

Hiroshi Komatsugawa, Hidenori Sugiyama, Wataru Ohata and Toshio Kawai
*Faculty of Photonics Science, Department of Applied Photonics System,
Chitose Institute of Science and Technology*
hiroshi@mail.chitose.ac.jp

Abstract

We have implemented Web-based training (WBT) system for mathematics on purpose of the practical use in the educational field. The system consists of electronic drills aiming the repeated practice and electronic texts aiming to improve students' interest for learning. The materials cover a wide course of mathematical study, such as curricula of junior high school and high school, and the fundamental course of the university. The electronic-drill (E-D) system built by the server side Java analyzes the results of the problem solving by use of rule-based evaluation functions and indicates the real-time selection for the next problem from fundamental, standard, and advanced courses. The electronic-text (E-T) system contains multimedia contents for the encouragement of users' interest. The content consists of mathematical expressions and animations constructed by use of XML format and controlled by functions of Flash. A series of educational system is examined in the test bed.

1. Introduction

High performance and low cost of computer equipments are leading to easy handling for multimedia applications defined as the integration of various informational media such as video and voice from live action, and three dimensional computer graphics (3DCG) in home use. In addition, the explosive spread of Internet technology representative for WWW evolves the capability of multimedia applications to perform multiple concurrent accesses[1]. As for education, consistent and systematic information education through all stages of school education will require sufficient improvement of related subjects and active use of computers in virtually every subject. Especially, Ministry of Education, Culture, Sports, Science and Technology in Japan recommends elementary schools to employ computers for children's learning activities in the period for integrated study and other classes is going to introduce the education of information science in the elementary education.

In Japan, while the period for the integrated study is encouraged, the decline of students' basic abilities and skills for science and mathematics becomes very serious

problem representative for "college students who cannot solve the calculation of fractions". In the basic mathematics education, students should take their time to learn arithmetic and should be repeatedly taught until they master the basic computation skills. In the balance between the integrated study and the remedial training, a new type of education tool is needed.

Using CAI for mathematical education based on multimedia technique, the teaching contents including character equations, symmetry of geometrical figures, three-dimensional figures such as a cone will be able to be easily expressed and be effective for the encouragement of users' interest for learning. Especially, the system with server-client architecture representative for TCP/IP network gives an individualized assessment of answers and problem solutions based on statistical analysis from the data recorded for all the users. Furthermore, teachers also keep accurate records, summarize data, project student-learning difficulties and assemble individualized tests. Furthermore, the system using open network representative for WWW offers more practical use[2].

The target of our study is the development of the WBT system for the improvement of students' fundamental learning abilities of mathematics through the remedial study. Especially, we aim the implementation of the practical educational applications and examine the system in the educational field.

2. The WBT System

2.1. System Structure

The user logging over WWW can use both electronic-drill (E-drill) system and electronic-text (E-text) system. The concept of the system is sketched in Fig.1. Our system is linear type of tutoring system in which users are requested to proceed to the next problems by answering correctly. Our system has also characteristic of a branching type because it offers course selection, assuming that users may frequently make mistakes [3].

Furthermore, for the encouragement of users' learning ability, the system offers multimedia materials and visualization of users' mark and ranking as indication.

In Fig.2, the system architecture is sketched. In the construction at server side, we use Java Servlet Server and Tomcat which is reference implementation of Java Servlet. The Servlet server manages user session, answer check, and analysis of users' learning history. PostgreSQL is employed as database server in which user information and the problem data with XML format are stored. The system is developed on Linux OS. At the client side, Mozilla is employed as Web browser because it has functions for mathematical expression corresponding with MathML. The users' results are visualized by use of Java Applet.

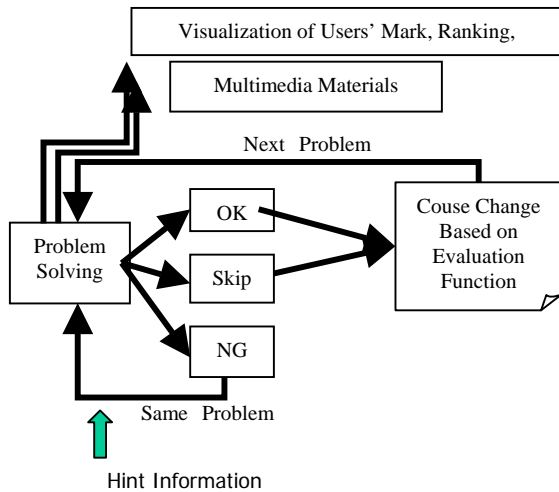


Figure1 System concept

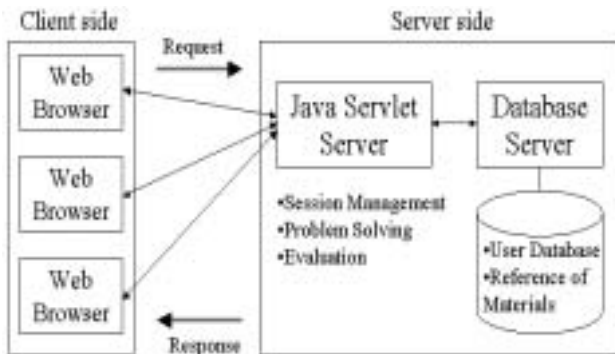


Figure2 System architecture

2.2. E-drill System

Problems in the E-drill system are classified in the sections corresponding with the courses of mathematical study such as integration, differentiation, and so on. Users can respond answers by inputting numerical numbers and characters. A sketch of sequential problems in a section is shown in Fig.3.

User interface of the E-drill system is shown in Fig.4. In the system, users can choose five types of actions that are (1) check of users' answer for the present problem, (2) skip of the present problem and advance to the next problem, (3) stop of the process of problem solving, (4) presentation of corresponding texts in the E-text system, and (5) visualization of users' mark and degree of understanding.

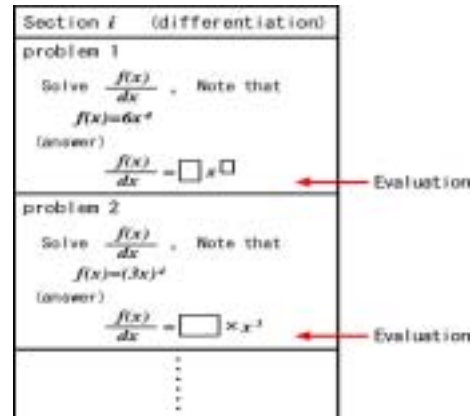


Figure3 Relations of problems and a section



Figure4 Overview of E-drill system

The main function of the E-drill system is presentation of drills matching the degree of users' understanding evaluated by the rule-based function. The detailed explanation of the function is mentioned in the next section. In the drill system, users' answer is analyzed at real time and the response to the current answer is returned to an individualized user. In case a user can respond a right answer, the system offers a next problem in an appropriate course determined from users' evaluation. In case a user cannot respond a right answer, the system offers the same problem with hint information or explanation of the problem. Hint information is given to users, depending on users' wrong numbers, whose values are predetermined by the teacher.

We aim supporting students' activities for learning through the repetition of problem solving in the same section. For this, firstly, the random numbers are adapted to the numerical coefficients of mathematical expressions of the problem determined by the mathematical rule between problems and answers. The example of XML description of problems including random numbers is shown in Fig.5. Second, we prepare three types per one problem, that is, fundamental, standard, and advanced courses. On basis of evaluation for the next problem solving, the degree of users' understanding is calculated and the course selection is performed. A series of procedures helps users to take several patterns for the problem solving in the same section. Third, we visualize the history of degree of understanding in the section as shown in Fig. 4. Furthermore, we supplement the functions of viewer of the ranking in the section for the top 20 persons. A series of functions is introduced so that students can keep interest based on numerical indications.

```

<question>
<define>
  <randomDefine danme="r" from "3" to "9"/>
</define>
r ranging from 3 to 9

<sentence> .....
  <mfrac>
    <mi>d</mi> <mi>dx</mi>
  </mfrac>
  <msubsup>
    <mi>x</mi>
    <mn><randomValue name="r" /></mn>
  </msubsup>
  <mo><mi>A</mi>
  <msubsup>
    <mi>B</mi>
  </msubsup>
</sentence>

<answer name="A" type="input"> A=[ ]
<randomValue name "r"/>
</answer>

```

```

<answer name="B" type="input"> <expression>
<randomValue name "r"/>-1
</expression></answer>
B=r-1
</question>

```

Figure5 XML format of a question file

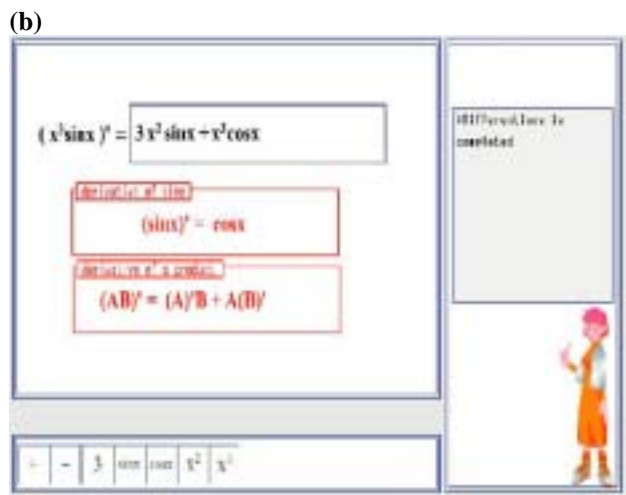
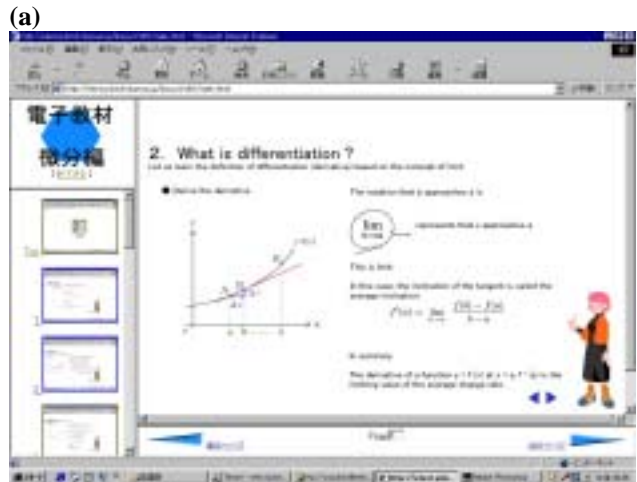


Figure6 The sample of user interface of E-text system

2.3. E-text System

The materials in the E-text system contain page files registered in the database describing the classification of the section. For the encouragement of students' understanding, we employ the multimedia technique including the voice and the animations. In the mathematics education, especially, it is important to show students the regular sequence for constructing the logic. In the present materials, we consider logical steps on basis of teachers' teaching experience in the actual

lesson and visualize the blackboard image drawn in the practical lessons as learning materials. Each material includes moving figures, expressions and characters. A sequence of elements is controlled in accordance with the scenario designated by the actual teachers (expert) participating in the present study.

Users can read stories in the material at their own pace by clicking the control button and confirming expressions or figures step by step. Fig.6 (a) and Fig6. (b) represent typical samples of the materials and the exercises, respectively. In Fig.6 (a), the concept of the limit is explained with the tangential relation of the line and the curve. Users can understand the material by watching the animation and clicking the button. In Fig.6 (b), users can drag components located on the bottom of the browser and input them into the blank, reviewing the explanation for problem solving. We prepare, in advance, the representative components such as sin, cos, and π , and explanations assuming the patterns of users' mistakes. We note that an unexpected mistake happens, the system only replies the message that something is wrong.

3. Evaluation Functions for Drills

In the E-drill system, we set a simple evaluation model for course selection from three levels of problems in a section. For the appropriate choice of the course, we introduce degree of users' understanding given by

$$\sigma_i = \frac{r_i + l_0}{r_i + w_i + g_i + l_0 \left(\frac{2}{\sigma_m + \sigma_n} \right)} \quad (1)$$

,where r_i , g_i , and w_i are right, skipped, wrong numbers of section i , respectively, and l_0 is initial cost to suppress a rapid change of users' course. The σ_i indicates the degree of users' understanding, ranging from 0 to 1. We set σ_n and σ_m as threshold value of σ_i between the fundamental and standard problems, and the standard and advanced problems, respectively. When a user select a section at the first time, σ_i becomes equal to $(\sigma_m + \sigma_n)/2$. This means that the initial selection is always chosen as standard course. With an increase of users' trial numbers, σ_i becomes close to the simple ratio of right numbers and trial numbers for problem solving.

We note that σ_m and σ_n are empirically designated by the expert (teacher) of mathematics or predetermined by the normalized values of (average \pm standard deviation) on basis of the results obtained from the previous paper test. The l_0 is also determined empirically. With a decrease of l_0 , the course changes depending on users' results occur frequently. In the present study, to suppress

a frequent course change, we set 10 problems in one section at $l_0=8$, $\sigma_m=0.7$, and $\sigma_n=0.3$. In this situation, no shift to the advanced course occurs although users who try the problem solving for the first time can solve perfectly all problems in the section. The first course change occurs at the second repetition of the same section. We note that the course change to the fundamental course may occur in the first try of the section if the user makes mistakes repeatedly.

Let us consider the qualitative relation with the degree of users' understanding and the courseware in the section. A conceptual sketch of courseware is shown in Fig.7. If a user starting from the standard course cannot solve problems, he may feel too hard to continue problem solving in this course. In this case, the system gives the same problem with several kinds of hint information. Owing to this hint information, this user may be able to solve the problem after the several trials or may fail in solving the problem. The degree of users' understanding calculated on basis of Eq. (1) indicates a low value due to the large w_i and g_i . In consequence, the system may introduce level down of the present course. On the contrary, the user solves the problems without hint information may feel too boring to continue the problem solving. In this case, the degree of users' understanding indicates a high value due to the low w_i and g_i . In consequence, a course change to level up may be induced.

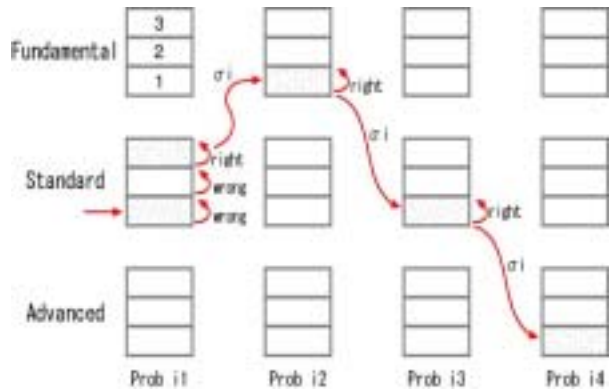


Figure7 Scheme of course selections

4. Management of Multimedia Contents

It is important for teachers to prepare original materials for improvement of students' learning abilities. Then, the easy management and maintenance of multimedia contents are inevitable factors for the educational system. For example, the Markup Language (ML) representative for the HTML has a merit to produce the contents on basis of the rule described by the text format.

The multimedia materials employed in the E-text system are constructed with SWF(Shock Wave FLASH) format and viewed by using a plug in of FLASH. In our study, the functions of ML supported in the SWF are utilized for the construction of contents. Furthermore, by use of script implemented in FLASH, we define several ML formats necessary for the present case study. The samples of ML are summarized in Tab. 1. The call of external SWF files is established by use of internal function of FLASH. Especially, the control functions of movies such as replay and playback are defined as attribute of ML. The mathematical expressions are defined as libraries of ML using vector format of FLASH.

Using the defined ML, users (teachers) can prepare the original multimedia materials by only making text files of ML format or components of FLASH animations. Furthermore, we use external SWF components for constructing the frame in the E-text system, which means that teachers can modify the frame design of the system.

Display the title in the E-text system	<title> </title>
Display the text streaming horizontally	<text> <text>
Display the static strings	<str> </str>
Display the Flash movie	<swf> </swf>
Display the math. Expression	$$
Display summation	<sum>..</sum>
Display Combination	<Cn/>
Display logarithm	<log/>
Display integration	<int/>
Display fraction	<frac>{ }{ }</frac>
Display upper character	<super> </super>
Display underline	<u> </u/>

Table 1 ML defined in the present study

5. A Case Study

In the present study, we assume the environment of the FTTH and actually design the high-speed LAN using optical fibers connected among the university, the city library, and several junior high schools. A series of the educational system is examined in this test bed.

We prepared materials in the E-text system and the problems in the E-drill system assuming the curricula of mathematical study in high schools and fundamental course in the university. The detailed content information is summarized in Tab. 2.

Firstly, the fundamental section of drills covering differentiation and integration was introduced as the examination to the freshmen in the university. The results of the examination were employed as a diagnostic test.

For use of the examination, we supplemented a new module to cover the examination in the E-drill system. The user interface of the system is shown in Fig.8. In this system, each student receives all problems from the server, and answers each problem, viewing other problems until submitting answers to the server. We note that the contexts of problems are the same in all students but parameters of mathematical expressions are modified by use of the random number. After the submission, users can watch their mark and the ranking of the examinations, and the detailed information for themselves at real time.

Section	Numbers of Exercises	Numbers of materials
Differentiation	30	20
Integration	20	15
Function	20	15
Complex number	20	15
Complex plane	20	15
Trigonometric function	20	20
Trigonometric ratio	20	15
Exponential function	10	10
Logarithmic function	10	10
Progression	30	20
Vectors	20	20
Quadratic function	20	15
Circle	20	15

Table 2 Curricula examined in the case study



Figure8 Overview of the examination

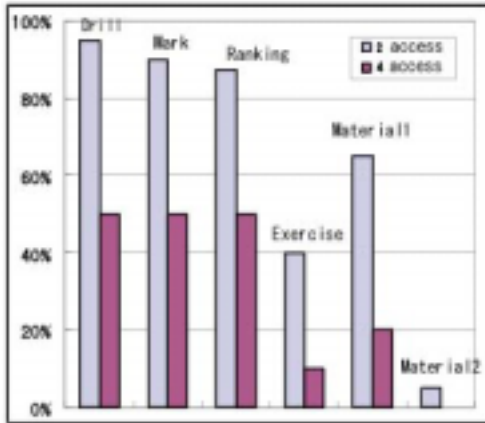


Figure9 Statistics of user access

Second, after the examination, we recommended students to determine voluntary selection for the extra mathematical lessons. We informed students that the lessons were on purpose of the review of high schools and junior high schools and, the WBT system used in the examination was partially introduced. In consequence, 20% of freshmen participated in the extra lesson. In these lessons, we adopted the system for the exercise time designated in the lesson, and measured users' access numbers to each module. The investigated modules are the problem solving for the drill, the request for viewing users' mark and ranking, the request for viewing the exercises and the materials in the E-text system. We note that the material 1 and 2 correspond with the multimedia contents used in the present study and the contents of PDF format prepared for comparison. The Fig 9 shows the ratio of corresponding student numbers and total student numbers at access numbers=2 and 4. We found that more than 90% students tried the drill repeatedly and viewed their results, and half of students repeated the E-drill system for four times. This result indicates that our system is effectively used for the remedial study of mathematics. As for the E-text system, most students used the multimedia materials rather than the materials of PDF format, which suggests the effectiveness of multimedia materials.

Thirdly, the WBT system was also examined over the Internet by the high school students admitted through the recommended entrance of the university. They were requested to learn the mathematical course given in the E-drill and E-text system by their graduation of the high school. Users' learning history was analyzed by the teachers who would lecture in the fundamental course of university. In consequence, before students entered the university, the teachers could prepare for the materials assuming the learning degree of coming students.

6. Conclusion

We developed the WBT system for mathematics assuming the practical use in the educational field. The E-drill system realizes course selections at each problem solving on basis of users' learning history. The E-text system offers multimedia materials imitating the blackboard image drawn in the teachers' lesson.

The merit for the practical use of our system is as follows:

- (1) The system is Web-based system and we need extra applications at client side without plug in of the browser.
- (2) The system offers individualized guidance with functions of real-time problem solving and course selection based on the rule-based evaluation function to consider remedial study in one section.
- (3) The system contains multimedia database covering a wide range of mathematical curricula and considering logical steps on basis of teachers' teaching experience in the actual lesson.
- (4) The system offers functions of easy maintenance of multimedia contents described by use of ML.

The points to improve our system are as follows.

- (1) The mathematical contents should be extended to the knowledge-based database classified on basis of the hierarchy of logics by teachers (human expert).
- (2) The relation with users' results of WBT and the multimedia contents as knowledge base should be analyzed by human expert.
- (3) The functions using symbolic evaluation for offering the appropriate materials should be supplemented.

References

- [1] Owen C.B. and Makedon F., Computed synchronization, for multimedia applications, sec.7, Kluwer Academic Pub. 1999.
- [2] Komatsugawa H. and Kawai T., A case study of electronic text and drill using WWW, ICME9 2000 pp.236.
- [3] Crowder N.A. Automatic tutoring by means of intrinsic programming in Galanter, Wiley NewYork, 1959.